Interdigitated Carbon Electrodes for Stem Cell Differentiation and Dopamine Detection

Bunea, Ada-Ioana; Amato, Letizia; Heiskanen, Arto; Larsen, Niels Bent; Keller, Stephan Sylvest; Emnéus, Jenny

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Ada-Ioana Bunea, Letizia Amato, Arto Heiskanen,
Niels Bent Larsen, Stephan Sylvest Keller, Jenny Emnéus
Produktionstorvet, Building 423, 2800 Kgs. Lyngby, Denmark
adabu@nanotech.dtu.dk

Introduction

Carbon is a material of great interest in tissue engineering and cell replacement therapies due to its high versatility and good biocompatibility. Pyrolysed 3D-carbon scaffolds have been shown to induce spontaneous differentiation of human neural stem cells into dopaminergic neurons with very high efficiency[1]. Moreover, due to their shape and conductivity, the scaffolds also offer better opportunities for the electrochemical detection of released dopamine.

Materials and methods

Fabrication (Fig. 1) of interdigitaded electrodes (IDEs) (Fig. 2) was performed using the cleanroom facilities in Danchip. SU-8 2005 was employed for obtaining a uniform layer of polymer on the bottom of the wafers – as working surface or support for the pillars – and SU-8 2075 was employed for obtaining the pillars[2]. The polymer was crosslinked in the areas of interest by masked UV exposure – 150 mJ/exposure. The obtained structures were developed and then pyrolysed at 900C in N_2 atmosphere. Two types of IDEs were fabricated and tested: flat 2D carbon electrodes and 3D carbon electrodes with pillars on the "fingers" of the IDE (Fig. 3), with the IDE array shown in Fig. 4.

Fabrication of the chip holders for the electrochemistry experiments was done using micromilling and laser ablation in the facilities at DTU Nanotech. The PCB used for interfacing the chip with the potentiostat was also designed and fabricated at DTU Nanotech (Fig. 5). Electrochemical results are shown in Fig 6 and 7.

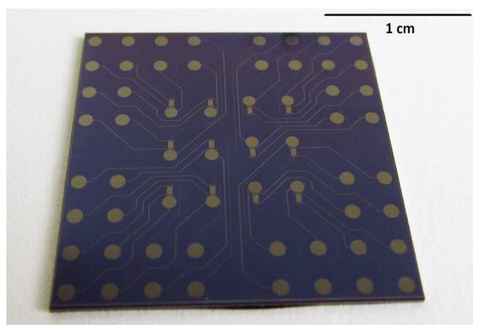

Fig. 4: *Electrode chip consisting of 12 fully functional electrodes and contact pads*

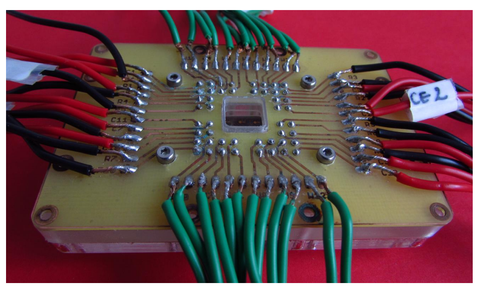

Fig. 5: *System employed in the electrochemistry experiments*

Fabrication

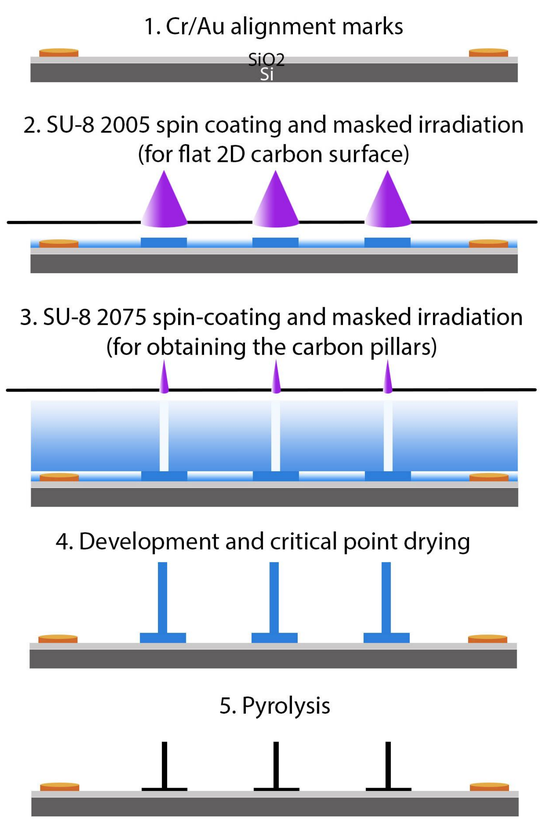

Fig. 1: *Fabrication process. For the 2D carbon electrodes step 3 is omitted*

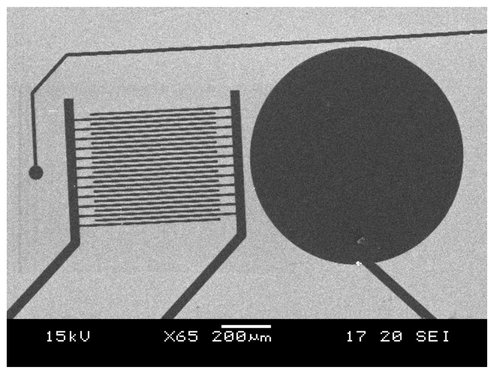

Fig. 2: *SEM image of working, reference and counter electrodes made of carbon*

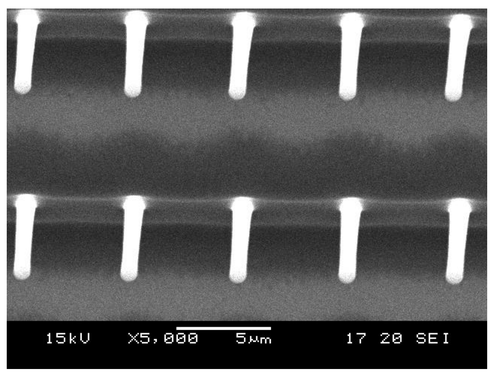

Fig. 3: *SEM image of carbon pillars on interdigitated carbon electrodes*

Electrochemistry

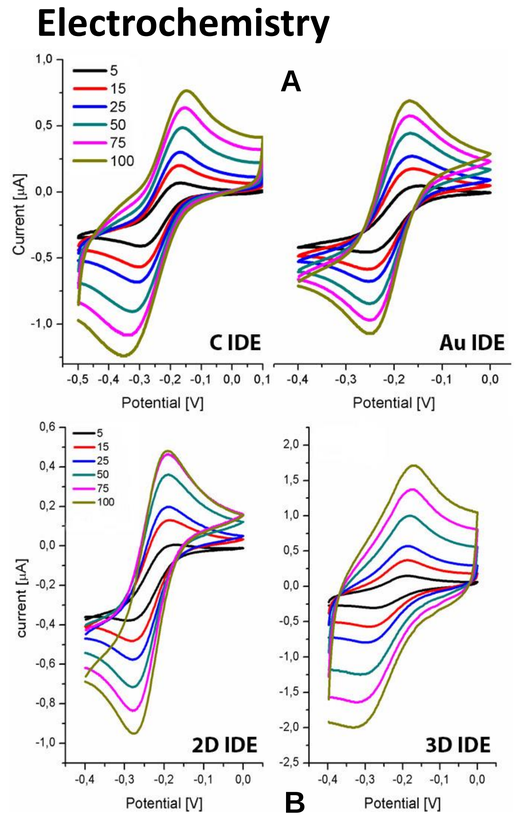

Fig. 6: *Cyclic voltammograms at different scan rates of 1 mM ruthenium (II/III) hexamine chloride in PBS (pH 7) on 2D IDE of pyrolysed carbon and gold (A) or on 2D and 3D carbon (B) (potentials vs. Ag/AgCl reference electrode)*

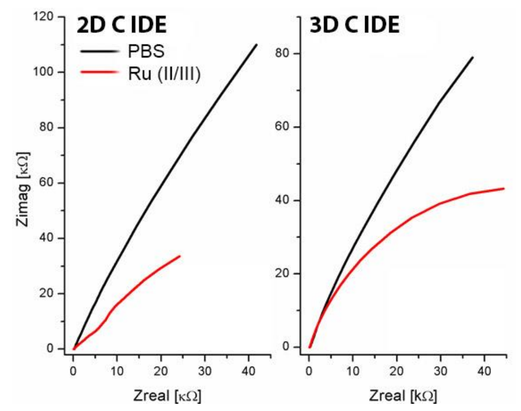

Fig. 7: *Nyquist plots for 2D and 3D IDE in 1 mM ruthenium (II/III) hexamine chloride or PBS (pH 7)*

Conclusions

The carbon IDE show similar or even improved performances compared to gold IDE.The chips can be employed both as substrate for cell growth / differentiation and as electrochemical sensors for dopamine released from mature dopaminergic neurons. The fact that each chip has 12 electrodes allows repeated measurements on different cell populations grown in the same conditions.

References

1. L. Amato et. al., Pyrolysed 3D-Carbon Scaffolds Induce Spontaneous Differentiation of Human Neural Stem Cells and Facilitate Real Time Dopamine Detection, *Advanced Functional Materials*, **2014**, Vol. 24, Issue 44, 7042-7052.
2. L. Amato et. al., Fabrication of high-aspect ratio SU-8 micropillar arrays, *Microelectronic Engineering,* **2012**, Vol. 98, 483-487.